GSFC 424-11-13-02

MISSION ASSURANCE REQUIREMENTS

FOR THE

TROPOSPHERIC EMISSION SPECTROMETER (TES)

AND THE

MICROWAVE LIMB SOUNDER (MLS)

INSTRUMENTS

FOR THE

EOS CHEMISTRY MISSION

13 NOVEMBER 1996

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

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SECTION 1

OVERALL REQUIREMENTS

1.1 DESCRIPTION OF OVERALL REQUIREMENTS

This document defines the mission assurance requirements for TES/MLS instruments. JPL is required to plan and implement an organized Assurance and Safety Program that encompasses all flight hardware and software from program initiation through launch operations. This program shall assure the integrity and safety of the flight instruments, and the ground support equipment which interfaces with flight instruments. In addition, JPL shall ensure that both TES and MLS instrument interface with the spacecraft is accurate.

The Flight Assurance Manager shall have direct access to the JPL's assurance management representative. The Assurance and Safety Program is applicable to JPL and its associated contractors and subcontractors.

1.2 USE OF PREVIOUSLY DESIGNED, FABRICATED, OR FLOWN HARDWARE

When hardware that was designed, fabricated, or flown on a previous program is considered to have demonstrated compliance with some or all of the requirements of this document such that certain tasks need not be repeated, JPL is required to demonstrate how the hardware complies with the requirements. JPL is required to present substantiating documentation at the instrument's design reviews.

1.3 SURVEILLANCE OF THE CONTRACTOR

The work activities, operations, and documentation provided by JPL or its subcontractors/suppliers are subject to evaluation, review, and inspection by government-designated representatives from GSFC, or an independent assurance contractor (IAC) as delegated by Flight Assurance Manager.

JPL, upon request, shall provide government assurance representatives with documents, records, and the access to equipment required to perform their assurance and safety activities. JPL shall also provide the GSFC or IAC assurance representative(s) with an acceptable work area within JPL facilities.

1.4 APPLICABLE DOCUMENTS (Appendix 12)

To the extent referenced herein, applicable portions of the documents listed in Section 12 form a part of this document.

SECTION 2

ASSURANCE DESIGN REVIEW REQUIREMENTS

2.1 GENERAL REQUIREMENTS

JPL shall conduct a series of comprehensive instrument-level reviews that are co-chaired by the GSFC Systems Review Office (SRO) and JPL. The reviews cover all aspects of instrument flight and ground hardware, software, and operations for which JPL has responsibility. In addition, JPL shall conduct a program of planned and documented peer reviews at the component and subsystem level for both instruments.

2.2 GSFC FLIGHT ASSURANCE DESIGN REVIEW REQUIREMENTS

Each specified instrument-level review conducted by JPL shall:

a. Develop and organize material for oral presentation to the co-chaired review team. Copies of the presentation material in accordance with the Data Requirements List shall be available at each review.

b. Support splinter review meetings resulting from the major review.

c. Produce written responses to the EOS Chemistry Project for recommendations and action items resulting from each review.

d. Summarize, as appropriate, the results of JPL peer reviews at the component and subsystem levels.

2.3 GSFC FLIGHT ASSURANCE DESIGN REVIEW PROGRAM

The Office of Flight Assurance (OFA) Design Review Program (DRP), shall consist of individual, periodic reviews of the TES and MLS instruments. These reviews shall include discussions of the flight hardware, flight software, and ground systems which interface with flight hardware.

a. <u>The Design Review Team</u>

The review team will include personnel from both JPL and GSFC experienced in subsystem design, systems engineering and integration, testing, and all other applicable disciplines. All reviews will be co-chaired by both JPL and GSFC SRO. The review chairpersons, in concert with the EOS Chemistry Project Manager and JPL shall appoint independent key technical experts as review team members. Personnel outside JPL and GSFC may be invited as members if it is believed that their expertise will enhance the design review team.

b. Design Reviews

(1) Co-chairs, in conjunction with the EOS Chemistry and JPL Project Managers, shall develop design review requirements to be documented during the TES/MLS instrument reviews. The following is a list of the required design reviews:

(a) Preliminary Design Review (PDR)--This review occurs early in the design phase but prior to manufacture of engineering hardware and the detailed design of associated software. Where applicable, it should include the results of test bedding, breadboard testing, and software prototyping. Long-lead procurements should be discussed.

(b) Critical Design Review (CDR)--This review occurs after the design has been completed but prior to the start of manufacturing flight components or the coding of software. It shall emphasize implementations of design approaches as well as test plans for flight systems including the results of engineering model testing.

(c) Pre-Environmental Review (PER)--This review occurs prior to the start of environmental testing of the flight instruments. The primary purpose of this review is to establish the readiness of the instruments for system level test and to evaluate the environmental test plans.

(d) Pre-Shipment Review (PSR)--This review shall take place prior to shipment of the instruments for integration with the observatory. The PSR shall concentrate on instrument performance during testing.

c. Design Review Schedule

The design review schedule will be mutually agreed to by the GSFC Systems Review Office (Code 301), GSFC Project Manager, and JPL management. TES and MLS shall have separate reviews unless agreed to by the co-chairs, EOS Chemistry Project Management, and JPL management.

d. System Safety

The safety aspects for both TES and MLS instruments are a normal consideration in the design evaluations conducted by the review board. System safety shall be an agenda item for each review listed, and as such shall serve to support the total system safety review program specified in Section 11 of this document.

2.4 JPL REVIEW REQUIREMENTS

JPL shall implement a program of peer reviews at the component and subsystem levels. The peer reviews shall evaluate the ability of the components and subsystems to successfully perform their function under operating and environmental conditions during both testing and flight. The results of parts stress analyses and component peer reviews, including the results of associated tests and analyses, shall be discussed at the instrument PDR and CDR.

The peer reviews shall specifically address the following:

a. Placement, mounting, and interconnection of EEE parts on circuit boards or substrates.

b. Structural support and thermal accommodation of the boards and substrates and their interconnections in the component design.

c. Provisions for protection of the parts and ease of inspection.

JPL peer reviews shall be conducted by personnel who are not directly responsible for design of the hardware under review. JPL will refer to all peer reviews in their schedule and GSFC reserves the right to attend these reviews. The results of the reviews shall be documented and the documents shall be made available for review at JPL.

SECTION 3

VERIFICATION REQUIREMENTS

3.1 GENERAL REQUIREMENTS

An instrument performance verification program documenting the overall verification plan, implementation, and results is required to ensure that the instrument meets the specified mission requirements, and to provide traceability from mission specification requirements to launch and on-orbit capability. The program consists of a series of functional demonstrations, analytical investigations, physical property measurements, and tests that simulate the environments encountered during handling and transportation, prelaunch, launch, and in-orbit. All protoflight hardware shall undergo qualification to demonstrate compliance with the verification requirements of this section. In addition, all other hardware (flight, and spare) shall undergo acceptance in accordance with the verification requirements of this section.

The Verification Program begins with functional testing of assemblies; it continues through functional and environmental testing supported by appropriate analysis, at the component, subsystem, instrument , and observatory levels of assembly. The program concludes with end-to-end testing of the entire operational system including the payload, the Payload Operations Control Center (POCC), and the appropriate network elements.

3.2 DOCUMENTATION REQUIREMENTS

3.2.1 Performance Verification Plan

A performance verification plan or it's equivalent shall be prepared defining the tasks and methods required to determine the ability of the instrument to meet each program-level performance requirement (structural, thermal, optical, electrical, guidance/control, RF/telemetry, science, mission operational, etc.) and to measure GSFC performance specification compliance. As agreed to by GSFC and JPL limitations in the ability to verify any performance requirement shall be addressed, including the addition of supplemental tests and/or analyses that will be performed and a risk assessment of the inability to verify the requirement.

The performance verification plan shall address how compliance with each specification requirement will be verified. If verification relies on the results of measurements and/or analyses performed at lower (or other) levels of assembly, this dependence shall be described.

For each analysis activity, the plan shall include objectives, a description of the mathematical model, assumptions on which the models will be based, required output, criteria for assessing the acceptability of the results, the interaction with related test activity, if any, and requirements for reports. Analysis results shall take into account tolerance build-ups in the parameters being used.

The performance verification plan shall also address environmental verification, stating the overall approach (listing tests and analyses) that will collectively demonstrate that the hardware and software comply with the environmental verification requirements. For each test, it shall include the level of assembly, the configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control requirements, test phases and profiles, necessary functional operations, personnel responsibilities, and requirement for procedures and reports. It shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described.

Limitations in the environmental verification program which preclude the verification by test of any system requirement shall be documented. This plan shall be submitted in accordance with Data Requirements List Item No. 022.

3.2.2 System Performance Verification Matrix

A System Performance Verification Matrix shall be prepared as part of the Performance Verification Plan, and maintained, to show each specification requirement, the reference source (to the specific paragraph or line item), the method of compliance, applicable procedure references, results, report reference numbers, etc. This matrix shall be included in the system review data packages showing the current verification status as applicable. It should be noted that this Performance Verification Test Matrix shall be included with the plan referenced in Section 3.2.1.

3.2.3 Environmental Test Matrix

As an adjunct to the Performance Verification Plan, an environmental test matrix shall be prepared that summarizes all tests that will be performed on each component, each subsystem, and the instrument. The purpose is to provide a ready reference to the contents of the test program in order to prevent the deletion of a portion thereof without an alternative means of accomplishing the objectives; All flight hardware, spares and prototypes (when appropriate) shall be included in the matrix. The matrix shall be prepared in conjunction with and included in the Performance Verification Plan and shall be updated as changes occur.

A complementary matrix shall be kept as part of the Performance Verification Plan showing the tests that have been performed on each component, subsystem, or instrument. This should include tests performed on prototypes or engineering units used in the qualification program, and should indicate test results (pass/fail or malfunctions).

3.2.4 Performance Verification Specification

A Performance Verification Specification shall be prepared that defines the specific environmental parameters that each hardware element is subjected to either by test or analysis in order to demonstrate its ability to meet the mission performance requirements. This specification shall be delivered as specified in the Data Requirements List Item No. 308.

3.2.5 Performance Verification Procedures

For each verification test activity conducted at the component, subsystem, and payload levels (or other appropriate levels) of assembly, a verification procedure shall be prepared that describes the configuration of the test article, and how each test activity contained in the verification plan and specification will be implemented.

Test procedures shall contain details such as instrumentation monitoring, facility control sequences, test article functions, test parameters, pass/fail criteria, quality control checkpoints, data collection and reporting requirements. The procedures also shall address safety and contamination control provisions. These procedures are not a required deliverable item, however, they shall be available for review upon request.

3.2.6 Verification Reports

After each component, subsystem, or instrument, verification activity has been completed, a report shall be prepared. For each environmental test activity, the report shall contain, as a minimum, the information in the sample test report contained in Figure 3-1. For each analysis activity, the report shall describe the degree to which the objectives were accomplished, how well the mathematical model was validated by related test data, and other such significant results. The Verification Reports shall be prepared within 30 days following the activity, and shall be available upon request. In addition, as-run verification procedures and all test and analysis data shall be retained for review.

3.3 ELECTRICAL FUNCTION TEST REQUIREMENTS

The following paragraphs describe the required electrical functional and performance tests that verify the instrument operation before, during, and after environmental testing. These tests along with all other calibrations, functional/performance tests, measurements/demonstrations, alignments (and alignment verifications), end-to-end tests, simulations, etc., that are part of the overall verification program shall be described in both the TES and MLS Performance Verification Plans.

3.3.1 Electrical Interface Tests

Before the integration of an assembly, component, or subsystem into the next higher hardware assembly, electrical interface tests shall be performed to verify that all interface signals are within acceptable limits of applicable performance specifications. Prior to mating with other hardware, electrical harnessing shall be tested to verify proper characteristics; such as, routing of electrical signals, impedance, isolation, and overall workmanship.

Figure 3-1

VERIFICATION TEST REPORT

Page _____ of _____

PROJECT ______________________________

TEST ITEM ______________________________

MANUFACTURER ______________________________

SERIAL NUMBER ______________________________

LEVEL OF ASSEMBLY

- ☐ SUBASSEMBLY or ASSEMBLY
- ☐ UNIT/COMPONENT
- ☐ SECTION
- ☐ SUBSYSTEM/INSTRUMENT
- ☐ MODULE
- ☐ SPACECRAFT/PAYLOAD

HARDWARE

- ☐ ENGINEERING MODEL
- ☐ PROTOTYPE
- ☐ PROTOFLIGHT
- ☐ FLIGHT
- ☐ SPARE

TEST

- ☐ INITIAL TEST
  - STARTING DATE OF INITIAL TEST ______________
- ☐ RETEST
  - ☐ PARTIAL
  - ☐ FULL

STRUCTURAL - MECHANICAL

- ☐ STRUCTURAL LOADS
  - ☐ STATIC
  - ☐ ACCEL.
  - ☐ SINE BURST
- ☐ VIBRATION
  - ☐ RANDOM
  - ☐ SINE
- ☐ ACOUSTICS
- ☐ MECHANICAL SHOCK
  - ☐ ACTUATION
  - ☐ SIMULATED
- ☐ MECHANICAL FUNCTION
- ☐ MODAL SURVEY
- ☐ PRESSURE PROFILE
- ☐ MASS PROPERTIES
- ☐ OTHER (explain)

ELECTROMAGNETIC COMPATIBILITY

- ☐ CONDUCTED EMISSIONS
- ☐ RADIATED EMISSION
- ☐ CONDUCTED SUSCEPTIBILITY
- ☐ RADIATED SUSCEPTIBILITY
- ☐ MAGNETIC PROPERTIES

ELECTRICAL PERFORMANCE

- ☐ LPT
- ☐ CPT
- ☐ END-TO-END
  - ☐ COMPATIBILITY TEST
  - ☐ MISSION SIMULATIONS

THERMAL

- ☐ THERMAL-VACUUM
  - (no. of cycles _____)
- ☐ THERMAL CYCLING
  - (no. of cycles _____)
- ☐ THERMAL BALANCE
- ☐ TEMPERATURE-HUMIDITY
- ☐ LEAKAGE
- ☐ OTHER (explain)

OPTICAL

- ☐ EXPLAIN

VERIFICATION PROCEDURE NO.: __________ REV. _____ DATE __________
APPLICABLE VERIFICATION PLAN: ______________________________
FACILITY DESCRIPTION: ______________________________
LOCATION: ______________________________
TEST LOG REFERENCE· ______________________________
COMMENTS·

SIGNATURES

COGNIZANT ENGINEER FOR TEST ITEM: ______________________________ DATE __________

QUALITY ASSURANCE REPRESENTATIVE: ______________________________ DATE: __________
(if required)

VERIFICATION TEST REPORT (Continued) Page_____of_____

DATE ADD TIME FOR THERMAL & TEMPERATURE TESTS	NOTE BEGINNING AND END OF ACTUAL ACTIVITY, DEVIATIONS FROM THE PLANNED PROCEDURE, AND DISCREPANCIES IN TEST TIMES PERFORMANCE. STATE IF THERE WERE NO DEVIATIONS OR DISCREPANCIES	MALFUNCTION REPORT NUMBER AND DATE AS APPLICABLE

The activities covered by these reports include tests and measurements performed for the purpose of verifying the flightworthiness of hardware at the component, subsystem, and payload levels of assembly. These reports shall also be provided for such other activities as the project may designate.

These reports shall be completed and transmitted to the GSFC Technical Officer or Contracting Officer (as appropriate) within 30 days after completion of an activity. Legible, reproducible, handwritten completed forms are acceptable.

Material felt necessary to clarify this report may be attached. However, in general, test logs and data should be retained by those responsible for the test item unless they are specifically requested.

The forms shall be signed by the quality assurance representative and the person responsible for the test or his designated representative; the signatures represent concurrence that the data is as accurate as possible given the constraints of time imposed by quick-response reporting.

This report does not replace the need for maintaining complete logs, records, etc.; it is intended to document the implementation of the verification program and to provide a minimum amount of information as to the performance of the test item.

3.3.2 Comprehensive Performance Tests

An appropriate comprehensive performance test (CPT) shall be conducted at the instrument and observatory levels. When environmental testing is performed at a given level of assembly, additional comprehensive performance tests shall be conducted during the hot and cold extremes of the temperature or thermal-vacuum test and at the conclusion of the environmental test sequence, as well as at other times prescribed in the verification plan, specification, and procedures.

The comprehensive performance test shall be a detailed demonstration that the hardware and software meet their performance requirements within allowable tolerances. The test shall demonstrate operation of all redundant circuitry and satisfactory performance in all operational modes. The initial CPT shall serve as a baseline against which the results of all later CPTs can be readily compared.

At the instrument level, the comprehensive performance test shall demonstrate that, with the application of known stimuli, the system will produce the expected responses. At lower levels of assembly, the test shall demonstrate that, when provided with appropriate inputs, internal performance is satisfactory and outputs are within acceptable limits.

3.3.3 Limited Performance Tests

Limited performance tests (LPT) shall be performed at the instrument and the observatory levels before, during, and after environmental tests, as appropriate, in order to demonstrate that functional capability of the instrument has not been degraded by the tests. The limited tests are also used in cases where comprehensive performance testing is not warranted. LPTs shall demonstrate that the performance of selected hardware and software functions is within acceptable limits. Specific times when LPTs will be performed shall be prescribed in the verification specification.

3.3.4 Aliveness Test

An aliveness test shall be performed to verify that the instrument and its major components are functioning, and that damage has not occurred as a result of environmental exposure, handling, transportation or faulty installation. This test shall be performed after major environmental tests, handling and transportation of the instrument, and shall be significantly shorter in duration than a CPT or LPT. Specific times when aliveness tests will be performed shall be prescribed in the verification specification. Both instruments will be subjected to an aliveness test at the observatory level.

3.3.5 Performance Operating Time and Failure-Free Performance Testing

At the conclusion of the performance verification program, payloads shall have demonstrated failure-free performance testing for at least the last 100 hours of operation. The demonstration may include operating time at the subsystem level of assembly when instrument testing provides insufficient test time to accumulate the trouble-free-operation, or when integration is accomplished at the launch site and the 100-hour demonstration cannot practicably be accomplished on the integrated payload. Failure-free operation during the thermal-vacuum test exposure is included as part of the demonstration of the trouble-free operation being logged at the hot-dwell and cold-dwell temperatures. Major hardware changes during or after the verification program shall invalidate previous demonstration.

3.3.6 Testing of Limited-Life Electrical Elements

A life test program shall be considered for electrical elements that have limited lifetimes as identified in the Limited-Life Items (section 7.4). The verification plan shall address the life test program, identifying the electrical elements that require such testing, describing the test hardware that will be used, and the test methods that will be employed.

3.4 STRUCTURAL AND MECHANICAL REQUIREMENTS

JPL shall demonstrate compliance with structural and mechanical requirements through a series of interdependent test and analysis activities. The demonstrations shall verify design and specified factors of safety, ensure launch vehicle interface compatibility, acceptable workmanship, and material integrity. In addition, certain activities needed to satisfy the safety requirements may best be accomplished in conjunction with these demonstrations.

When planning the tests and analyses, the developer shall consider all expected environments including those of structural loads, vibroacoustics, mechanical shock, and pressure profiles. Mass properties and mechanical functioning shall also be verified.

The program outlined below assumes that the design of the instrument is sufficiently modularized to permit realistic environmental exposures at the subsystem level. It is emphasized that each subsystem of the instrument (structure, power, command and data handling, etc.) must be verified for each of the requirements identified below. In some cases, it may be desirable to satisfy the requirements by test at the system or component level of assembly in lieu of testing at the subsystem level.

It is the JPL's responsibility to develop and document a meaningful set of activities that, best demonstrate compliance with the requirements.

3.4.1 Structural Loads

3.4.1.1 Design Verification

Verification for the structural loads environment shall be accomplished by a combination of test and analysis. A modal survey shall be performed at the system level to verify that the analytic model adequately represents the hardware's dynamic characteristics. The test-verified model shall then be used to predict the maximum expected load for each potentially critical loading condition, including handling, transportation, and vibroacoustic effects during lift-off. The maximum loads resulting from the analysis define the limit loads.

The usual method of verifying the hardware for adequate design strength is to apply a set of loads equal to 1.25 times the limit loads after which the hardware must be capable of meeting its performance criteria. In order to comply with safety and performance criteria, the strength verification test must be accompanied by a stress analysis that predicts that no ultimate failure will occur at loads equal to 1.40 times limit.

All beryllium primary and secondary structural elements shall undergo a strength test to 1.4 times limit load and be accompanied by a stress analysis that predicts that no ultimate failure will occur at loads equal to 1.60 times limit.

If appropriate development tests are performed to verify accuracy of the stress model, and stringent quality control procedures are invoked to ensure conformance of the structure to the design, then strength verification may be accomplished without test by a stress analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the limit load, and positive margin on ultimate at loads equal to 2.6 times the limit load.

Analysis alone shall not be used to verify the strength of elements fabricated from composite materials or beryllium.

The use of materials that are susceptible to brittle fracture or stress-corrosion cracking require definition of and strict adherence to appropriate additional procedures to prevent problems.

It is emphasized that all structural elements shall be in compliance with applicable safety requirements discussed in Section 11 of this document.

3.4.1.2 Flight Acceptance

Structural design loads testing is not required for flight structure that has been previously qualified for the current mission as part of a valid protoflight test. The following acceptance/proof loads tests are required (acceptance tests are not required on protoflight hardware that has been subjected to qualification levels):

(1) Beryllium structure (primary and secondary) shall be proof tested to 1.4 times limit load.

(2) Nonmetallic composites (including metal matrix) structural elements shall be proof tested to 1.25 times limit load.

(3) Bonded structural joints shall be proof tested (by static loads test) to 1.25 times limit load.

3.4.2 Vibroacoustics

3.4.2.1 Design Verification

To satisfy the vibroacoustic requirements, a design verification test program shall be developed which is based on an assessment of the expected mission environments. For both TES and MLS instrument's, an acoustic test at the instrument level is required along with random vibration tests in all three axes.

For verification, the input test levels are 3 dB above the maximum expected flight environment. When random vibration levels are determined, responses to the acoustic inputs plus the effects of vibration transmitted through the structure shall be considered. As a minimum, component random vibration levels shall be sufficient to demonstrate acceptable workmanship. Similarly, the minimum overall acoustic sound pressure level for any acoustic test should be 138 dB.

3.4.2.2 Flight Acceptance

For the acceptance of previously qualified hardware, testing shall be conducted at the maximum expected flight levels, or minimum workmanship levels, whichever is greater.

3.4.3 Sinusoidal Sweep Vibration Verification

3.4.3.1 Design Verification

Both instruments shall be subjected to a sine sweep vibration to verify their ability to survive the low-frequency launch environment. The test also provides a workmanship vibration test for payload hardware which normally does not respond significantly to the vibroacoustic environment at frequencies below 50 Hz, such as wiring harnesses and stowed appendages, but can experience significant responses from low-frequency sine transient vibration and any sustained, pogo-like sine vibration. It should be noted that sine sweep test will be performed at the spacecraft level.

For the sinusoidal vibration environment, the verification level is defined as the limit level times 1.25, and the test input frequency range shall be limited to the band from 5 to 50 Hz

Instrument and Component Sine Sweep Vibration Tests - As a screen for design and workmanship defects, these items shall be subjected to a sine sweep vibration test along each of three mutually perpendicular axes.

3.4.3.2 Flight Acceptance

Sine sweep vibration testing for the acceptance of previously qualified hardware shall be conducted at the flight limit levels using the same sweep rates as used for protoflight hardware.

3.4.4 Mechanical Shock

3.4.4.1 Design Verification

Both self-induced and externally induced shocks shall be considered in defining the mechanical shock environment. All subsystems shall be exposed to all self-induced shocks by actuation of the shock-producing devices. Each device must be actuated a minimum of two times in order to account for the scatter associated with different actuation's of the same device.

In addition, when the most severe shock is externally induced, a suitable simulation of that shock shall be applied at the subsystem interface. When it is feasible to apply the shock with a controllable shock-generating device, the verification level shall be 1.4 times the maximum expected value at the subsystem interface, applied once in each of the three axes. If it is not feasible to apply the shock with a controllable shock-generating device (e.g., the subsystem is too large for the device), the test may be conducted at the payload level by actuating the shock-producing devices in the payload that produce the shocks external to the subsystem to be tested. The shock-producing device(s) must be actuated a minimum of two times for the test.

3.4.4.2 Flight Acceptance

The need for Mechanical shock tests for the acceptance of previously qualified hardware shall be considered on a case-by-case basis. Testing should be given careful consideration in accordance with mission reliability goals, shock severity, hardware susceptibility, and design changes that could affect proximity to the shock-producing device, and previous history.

3.4.5 Mechanical Function

3.4.5.1 Design Verification

A kinematics analysis of all instrument mechanical operations is required (a) to ensure that each mechanism can perform satisfactorily and has adequate margins under worst-case conditions, (b) to ensure that satisfactory clearances exist for both the stowed and operational configurations as well as during any mechanical operation and (c) to ensure that all mechanical elements are capable of withstanding the worst-case loads that may be encountered.

Instrument verification tests are required to demonstrate that the installation of each mechanical device is correct and that no problems exist that will prevent proper operation of the mechanism during mission life.

Subsystem verification tests are required for each mechanical operation at nominal, low, and high-energy levels. To establish that functioning is proper for normal operations, the nominal test shall be conducted at the most probable conditions expected during normal flight. A high-energy test and a low-energy test shall also be conducted to prove positive margins of strength and function. The levels of the tests shall demonstrate margins beyond the nominal conditions to cover adverse interaction of potential extremes of parameters such as temperature, friction, spring forces, stiffness of electrical cabling or thermal insulation, and spin rate. Parameters to be varied during these high- and low-energy tests shall include, to the maximum extent practicable, all those that could substantively affect the operation of the mechanism as determined by the results of analytic predictions or development tests. As a minimum, successful operation at temperature extremes 10°C beyond the range of expected flight temperatures shall be demonstrated.

3.4.5.2 Life Testing

A life test program shall be implemented for mechanical and electromechanical devices such as gyros, scanners, and that move repetitively as part of their normal function and whose useful life must be determined in order to verify their adequacy for the mission. JPL and its subcontractor's shall identify such limited life items and the life testing approach (including augmenting analysis) in the Performance Verification Plan. Trend analysis and reporting shall be as specified in Section 7.3, Analysis of Test Data, and Section 7.4, Limited Life Items.

For limited life items for which life-testing will not be performed, the rationale for eliminating the test shall be provided along with a description of the analyses that will be done to verify the validity of the rationale.

3.4.5.3 Torque Ratio

The torque ratio requirement defined below applies to all mechanical functions, those driven by motors as well as springs, at beginning of life (BOL) only; end of life (EOL) mechanism performance is determined by life testing as discussed in paragraph 3.4.5.2. For linear devices, the term "force" shall replace "torque" throughout the section.

Torque ratios shall be verified by test both before and after exposure to environmental testing. Testing shall be performed at the highest possible level of assembly, in all positions, under worst-case BOL environmental conditions, representing the worst-case combination of maximum and/or minimum predicted (not qualification) temperatures, gradients, voltage, vacuum, etc.

The torque ratio is then given by:

$$TR = T_{avail}/T_{res}$$

The minimum available torque of the prime mover, T_{avail}, shall be verified by testing of individual motors, deployment springs, etc. in all positions. The measurement of available torque shall not include the mechanical advantage of harmonic drives or gear systems. Kick-off springs which do not operate over the entire range of the mechanical function shall be neglected. The minimum available torque shall never be less than 1 in-oz.

The maximum resistive torque of the driven system, T_{res}, shall be verified by testing of the fully-assembled, driven portion of the mechanism at all operational positions. For systems that include (velocity dependent) dampers, and are deployable rate independent, it is allowable to characterize (as nearly as possible) only the frictional resistive torque. For systems that include dampers and are deployable rate dependent, appropriate measures shall be taken to properly account for (as nearly as possible) the resistive torque produced by the dampers.

The minimum required test-verified torque ratios for various types of mechanism systems prior to environmental testing are:

System Type	TR_{min}
Systems which are dominated by resistive torque's due to inertia, such as momentum and reaction wheels	1.5
Systems which are dominated by resistive torque's due to a combination of both inertia and friction, such as large pointing platforms and heavy deployable systems	2.25
Systems which are dominated by resistive torque's due to friction, such as deployment mechanisms, solar array drives, cable wraps, and despun platforms	3.0

After exposure to environmental testing, the reduction (if any) in test-verified torque ratio shall be no greater than 10%, after appropriate consideration has been given to the error inherent in the test methods used to measure the torque ratio.

The required torque ratios should be appropriately higher than given above if:

a. The designs involve an unusually large degree of uncertainty in the characterization of resistive torque's.

b. The torque ratio testing is not performed in the required environmental conditions or is not repeatable.

c. The torque ratio testing is performed at the component level.

3.4.5.4 Acceptance Requirements - For the acceptance testing of previously qualified hardware, the payload and subsystem tests shall be performed, except that the subsystem tests need be performed only at the nominal energy level. Adequate torque ratio shall be demonstrated for all flight mechanisms.

3.4.6 Pressure Profile

3.4.6.1 Design Verification

The need for a pressure profile test shall be assessed for all subsystems. A verification test shall be performed if analysis does not indicate a positive margin at loads equal to twice those induced by the maximum expected pressure differential during launch. If a test is required, the limit pressure profile is determined by the predicted pressure-time profile for the nominal trajectory of the particular mission. Because pressure-induced loads vary with the square of the rate of change, the verification pressure profile is determined by multiplying the predicted pressure rate of change by a factor of 1.12 (the square root of 1.25, the required qualification factor on load).

3.4.6.2 Flight Acceptance

Pressure profile test requirements do not apply for the acceptance testing of previously qualified hardware.

3.4.7 Mass Properties

The mass properties program must include an analytic assessment of the payload's ability to comply with the mission requirements, including constraints imposed by the launch vehicle, supplemented as necessary by measurement. As a minimum, the instrument weight, mass, center of gravity, and moments of inertia must be measured and the results included in the Acceptance Data Package (Data Requirements List Item No. 526) During the instrument development, it is required that this data be reported in the monthly reports and discussed at quarterly and design reviews. In addition, a comprehensive alignment program shall be included.

3.5 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS

It is required that the electromagnetic characteristics of hardware be such that:

a. The instrument and its elements shall not generate electromagnetic interference that could adversely affect its own subsystems and components, other instruments, the spacecraft, or the safety and operation of the launch vehicle, or the launch site.

b. The instrument and its subsystems and components shall not be susceptible to emissions that could adversely affect their safety and performance. This applies whether the emissions are self-generated or derive from other sources, or whether they are intentional or unintentional.

3.5.1 Specific Requirements

JPL shall demonstrate compliance with the requirements by conducting an appropriate combination of EMC tests at the component, subsystem, and system levels of assembly.

At the component and instrument levels, JPL shall perform the various tests as indicated in Table 3-1. It should be noted that at the observatory level, the instrument will be subjected to specific EMC testing as referenced in Table 3-1. The design and workmanship of both instruments shall be able to withstand all the EMC tests required at each level.

The tests shall be performed against fixed limits as given in GEVS-SE. Other mission-specific requirements may be found in launch vehicle and launch site requirements documents. Requirements more stringent than GEVS shall be imposed when needed to meet specific mission requirements.

3.5.2 Flight Acceptance

The EMC verification test program shall be imposed on all flight hardware to detect unit-to-unit variations in materials, and workmanship defects.

Table 3-1 EMC Requirements per Level of Assembly

Type	Test	Component	Instrument	Observatory(*)
CE	DC power leads	R	R	-
CE	Power Leads	R	R	-
RE	AC magnetic fields	R	R	R
RE	E-fields	R	R	R
CS	Pwr lines	R	R	-
CS	Pwr line transients	R	R	-
RS	E-field (general)	R	R	R
RS	Magnetic field susceptibility	R	R	R
	Magnetic properties	R	R	R

CE - Conducted Emission; CS - Conducted Susceptibility.
R - Test to ensure reliable operation of hardware, and to help ensure compatibility with the ELV and launch site.
RE - Radiated Emission; RS - Radiated Susceptibility.
* - Observatory requirements apply when instrument is integrated; Test is Observatory contractor responsibility.

3.6 VACUUM, THERMAL, AND HUMIDITY REQUIREMENTS

In the vacuum, thermal, and humidity areas it must be demonstrated that:

a. The instrument shall perform satisfactorily in the vacuum and thermal environment of space.

b. The thermal design and the thermal control system shall maintain the affected hardware within the established mission thermal limits.

c. The hardware shall withstand, as necessary, the temperature and humidity conditions of transportation, storage, and ELV launch.

JPL shall demonstrate compliance by conducting a set of tests and analyses that collectively meet the requirements defined in the following paragraphs. Tests may require supporting analyses and vice versa.

3.6.1 Thermal-Vacuum

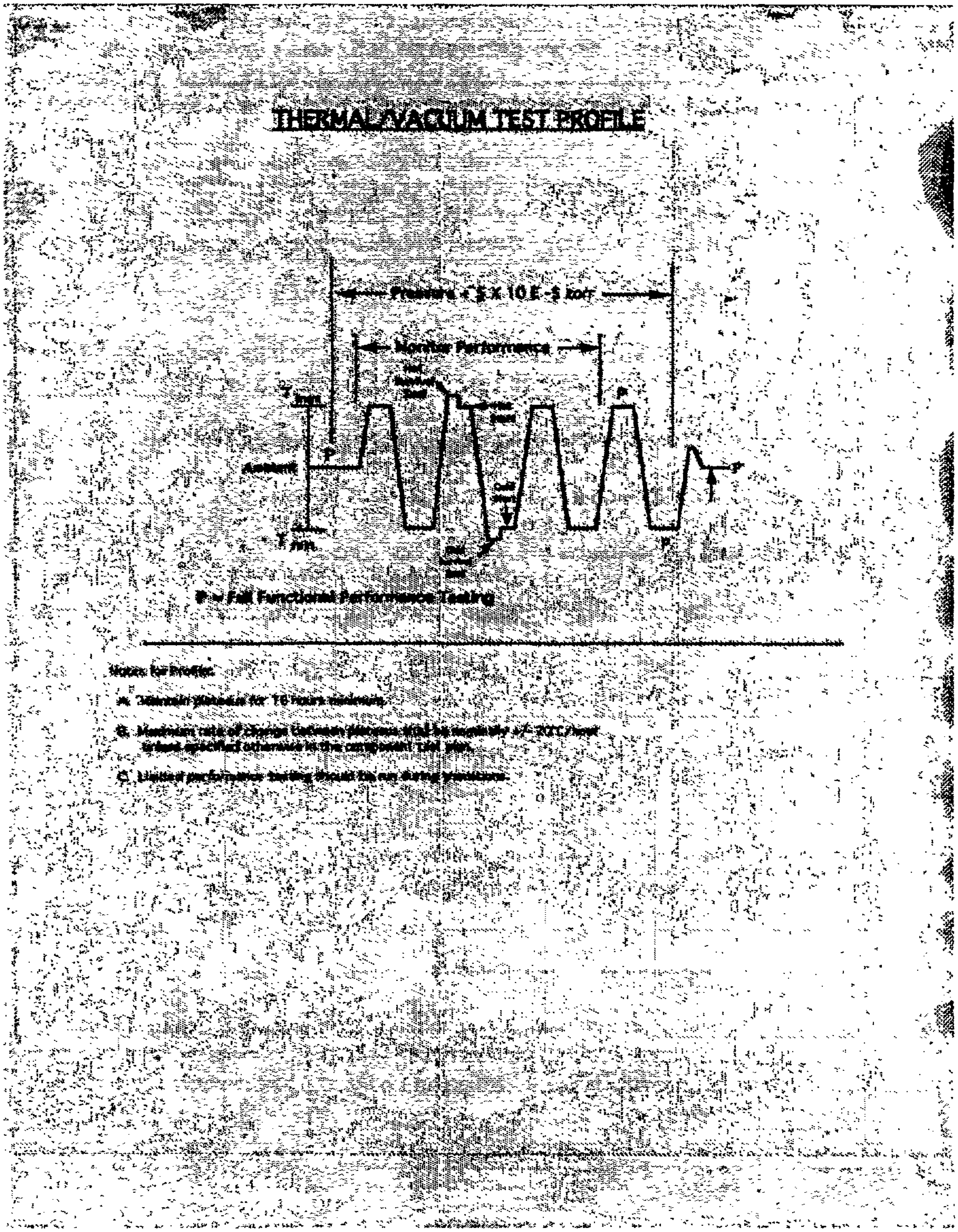
3.6.1.1 Design Verification

The thermal-vacuum test shall demonstrate the ability of the instrument to perform satisfactorily in functional modes representative of the mission in vacuum at the nominal mission operating temperatures, at temperatures 10 degrees C beyond the predicted instrument extremes, and during temperature transitions. The test shall also demonstrate the ability of the instrument to perform satisfactorily after being exposed to the predicted nonfunctional extremes of the mission, including the 10 degrees C margin. Cold and hot turn-on's shall be demonstrated.

Prior to instrument delivery, components shall be subjected to a minimum of 8 thermal-vacuum temperature cycles, at least four of which shall be at the instrument level. As a part of observatory testing, they will be subjected to at least 4 thermal-vacuum temperature cycles. During any thermal-vacuum cycling, the rate of temperature change shall not exceed 20 degrees C per hour, and soak times at temperature extremes shall not start until equilibrium is reached. For the instrument-level tests, the instrument shall be subjected to a minimum of 4 thermal-vacuum temperature cycles, during which the instrument shall be soaked for a minimum of 16 hours at each temperature extreme of each cycle. JPL shall state in the Verification Plan, the proposed testing scenario for the instrument and its components. The hardware at all levels of assembly shall be operated and its performance monitored throughout the test. Instrument turn-on capability shall be demonstrated at least twice during the low and high temperature extremes. The ability to function through the voltage breakdown region, if applicable, shall be demonstrated. Figure 3-2 presents a representative thermal-vacuum profile.

It should be noted that longer soaks will be performed at the observatory level. The instrument, at all levels of assembly, shall be operated and its performance monitored throughout the test.

Figure 3-2
Thermal/Vacuum Test Profile



Temperature excursions during the cycling of components shall be sufficiently large to detect latent defects in workmanship. Components that are determined by analysis to be insensitive to vacuum effects may be temperature-cycled at normal room pressure in an air or gaseous nitrogen environment. Additional margin and cycles; however, are required if air temperature is employed.

During final instrument thermal vacuum testing, the developer shall verify that the contamination bake-out criteria of Section 9 of this document and both the TES and MLS Contamination Control Plans are complied with.

3.6.1.2 Flight Acceptance

For the acceptance testing of previously qualified hardware, the verification requirements apply except that testing shall be conducted at either the predicted mission extreme temperatures, or a temperature deviation intended to detect variations in materials and workmanship defects, whichever is greater.

3.6.2 Thermal Balance Design Verification

The validity of the thermal design and the ability of the thermal control system to maintain the hardware within the established thermal limits for the mission shall be demonstrated by test.

The capability of the thermal control system shall be demonstrated in the same manner. If the flight hardware is not used in the test of the thermal control system, verification of critical thermal properties (such as those of the thermal control coatings) shall be performed to demonstrate similarity between the item tested and the flight hardware.

3.6.2.1 Flight Acceptance

For the acceptance testing of previously qualified hardware, a single point check shall be made to verify that the thermal model adequately represents the "as built" hardware.

3.6.3 Temperature - Humidity: Transportation and Storage

An analysis and, when necessary, tests shall demonstrate that flight hardware that is not maintained in a controlled temperature-humidity environment to within demonstrated acceptable limits, will perform satisfactorily after (or, if so required, during) exposure to the uncontrolled environment.

The test shall include exposure of the hardware to the following extremes of temperature and humidity:

Ten (10) degrees C and 10% RH (but not greater than 50% RH) higher and lower than those predicted for the transportation and storage environments. The exposure at each extreme shall be for a period of six (6) hours.

3.6.3.1 Acceptance Requirements

The ten (10) degree C temperature margin and the ten (10) percent RH margin may be waived for previously qualified hardware.

3.6.4 Leakage

This test shall demonstrate that leakage rates of sealed hardware are within those prescribed mission limits for the instrument; it applies to the qualification of hardware and the acceptance of hardware previously qualified.

Leakage rates shall be checked before and after stress-inducing portions of the verification program to disclose anomalies caused by the stress. The final check may be conducted during the final thermal-vacuum test.

Checks at the instrument level need include only those items that have not demonstrated satisfactory performance at the component level or are not fully assembled until higher levels of integration.

SECTION 4

ELECTRONIC PACKAGING
AND
PROCESSES REQUIREMENTS

4.1 GENERAL

JPL shall plan and implement an Electronic Packaging and Processes Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet the TES and MLS instruments objectives for quality and reliability.

4.2 WORKMANSHIP

JPL shall use their own internal workmanship standards entitled "Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling" (JPL D-8208), and "Electrostatic Control for Assemblies and Test Areas" (JPL D-1348).

JPL shall test their own printed wiring board coupons in accordance with both their own internal procedures as discussed in D-8208 and MIL-P-55110.

4.3 NEW/ADVANCED PACKAGING TECHNOLOGIES

New and/or advanced packaging technologies (e.g., MCMs, stacked memories, ASICs) that have not previously been used in space flight applications shall be reviewed during the Parts Control Meetings. New/advanced technologies shall be part of the Parts Identification List (PIL).

SECTION 5

PARTS

5.1 GENERAL

JPL shall plan and implement an Electrical, Electronic, and Electromechanical (EEE) Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability.

Provided that parts taken from flight stores were procured and processed in accordance with paragraph 5.2.2, then these parts are not required to be functionally tested prior to kitting, preparation for and use on flight hardware printed circuit boards.

JPL shall implement a parts control program describing the approach and methodology for implementing the Parts Control Program. The program shall define JPL's criteria for parts selection and approval based on the guidelines of this section.

5.2 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

5.2.1 Parts Control Meetings

JPL shall establish a documented system to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the program. This system shall be responsible for the review and approval of all parts for conformance to program requirements. Under this system, parts information shall be shared between the JPL and GSFC Part Engineers to identify all parts used, failure investigations, disposition of non-conformance's, and problem resolutions. Part meetings shall be convened on a regular basis or as needed. Meeting minutes or records shall be maintained by JPL to document all decisions made and a copy shall be provided to GSFC upon request. GSFC and JPL parts representatives shall attend all Parts Control Meetings and reach joint decisions on parts issues.

5.2.2 Parts Selection and Processing

Parts selection and processing will be determined at the parts control meetings. GSFC 311-INST-001, Instructions for EEE Parts Selection, Screening, and Qualification, Parts Quality 2 level, shall be used as baseline requirements for the instrument.

5.2.2.1 Custom Devices

Any custom microcircuits, hybrid microcircuits, MCM, ASIC, etc. planned for use by JPL shall be discussed with GSFC during the program parts control meetings.

5.2.3 Derating

Parts used in instrument flight hardware applications shall be derated in accordance with JPL derating procedure No. JPL D-8545, entitled "Electronic Parts Reliability Section 514 Derating Guidelines". This procedure shall be made available for GSFC review.

5.2.4 Radiation Hardness

All parts shall be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of two separate effects, those of total ionizing dose and single-event effects. JPL shall document the analysis for each part with respect to both effects.

5.2.5 Verification Testing

Verification of screening is not required unless deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. Verification of qualification tests shall be determined in the Parts Control Meetings on a case by case basis. If required, testing per JPL procedures shall be performed. JPL, however, shall be responsible for the performance of supplier audits, surveys, source inspections, witnessing of tests, and/or data review to verify conformance to established requirements.

5.2.6 Destructive Physical Analysis

A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices shall be subjected to a Destructive Physical Analysis (DPA). All other parts may require a sample DPA if it is deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. DPA tests, procedures, sample size and criteria shall be as specified in JPL procedure ZPP-2078-GEN. Variation to the DPA sample size requirements, due to part complexity, availability or cost, shall be discussed with the GSFC parts engineer on a case-by-case basis. In addition to the parts stated, JPL shall perform DPA on filters. Also, JPL is not required to perform DPA on ceramic capacitors if the QPL supplier already performs it.

5.2.7 Parts Age Control

Parts drawn from controlled storage after 5 years from the date of the last full screen shall be subjected to a 100 percent visual examination and electrical testing at room temperature, as a minimum. Additional testing including DPA, shall be determined by the PCB as deemed necessary. Parts stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall not be used.

5.3 PARTS LISTS

JPL shall create and maintain an as-designed Parts Identification List (PIL) for the duration of the program. The as-designed PIL shall list all parts planned for use in flight hardware. Parts reviewed and approved at parts control meetings shall be identified as such on the PIL. During the parts control meetings, this as-designed list will be reviewed by GSFC to insure compliance with the Level 2 parts requirements. The list will be informally made available to GSFC throughout the program, and shall also be presented at the PDR and CDR for GSFC review. An As-Built Parts List (ABPL) shall also be prepared and submitted to GSFC as part of each instruments Acceptance Data Package. Both the as-designed and as-built parts lists will be provided to GSFC in magnetic media form whenever such material is generated under JPL cognizance.

5.4 Alerts

JPL shall be responsible for reviewing and dispositioning all Government Industry Data Exchange Program (GIDEP) Alerts for applicability to the parts proposed for use. In addition, any NASA Alerts and Advisories provided by GSFC to JPL shall be reviewed and dispositioned. Alert applicability, impact, and corrective actions shall be documented and made available to GSFC.

SECTION 6

MATERIALS, PROCESSES AND LUBRICATION REQUIREMENTS

6.1 GENERAL REQUIREMENTS

JPL shall implement a comprehensive Materials and Processes Plan beginning at the design stage of each instrument that meets the contamination levels of the observatory and does not negatively impact the other instruments. The program shall help ensure the success and safety of the mission by the appropriate selection, processing, inspection, and testing of the materials and lubricants employed to meet the operational requirements for the TES and MLS instruments. Materials and lubrication assurance information is required for each usage or application for both TES and MLS instruments. The as-designed materials and processes list shall include lubrication, polymeric, and inorganic materials along with a list of the processes expected for use on the flight instruments. A separate materials and processes list shall be submitted for each instrument. This as-designed materials and processes list shall be available to GSFC upon request and shall be presented at the PDR and CDR. An as-built materials and processes list shall be submitted as part of each instrument's Acceptance Data Package.

6.2 MATERIALS SELECTION REQUIREMENTS

In order to anticipate and minimize materials problems during instrument's development and operation, JPL shall, when selecting materials and lubricants, consider potential problem areas such as radiation effects, thermal cycling, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled surfaces, composite materials, atomic oxygen, useful life, vacuum outgassing, flammability and fracture toughness, as well as the properties required by each material usage or application.

6.2.1 Compliant Materials

JPL shall use compliant materials in the fabrication of flight hardware to the extent practicable.

In order to be compliant, a material must be used in a conventional application and meet the criteria identified in Table 6.1.

6.2.2 Noncompliant Materials

A material that does not meet the requirements of Table 6.1, or meets the requirements of Table 6.1, but is used in an unconventional application, shall be considered to be a noncompliant material. JPL shall provide an open loop of communication for the GSFC Materials Engineer to assess and recommend approval of the noncompliant materials.

6.2.2.1 Materials Used in "Off-the-Shelf-Hardware"

"Off-the-shelf hardware" for which a detailed materials list is not available and where the included materials cannot be easily identified and/or changed shall be treated as noncompliant. JPL shall define on a MUA, what measures will be used to ensure that all materials in the hardware are acceptable for use. Such measures might include any one, or a combination, of the following: hermetic sealing, vacuum bakeout, material changes for known noncompliant materials, etc. When a vacuum bakeout is the selected method, it must incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bakeout as well as compliance with both TES/MLS instrument's contamination plan.

TABLE 6-1

MATERIAL SELECTION CRITERIA

Type Launch	Payload Location	Flammability	Vacuum Outgassing	Stress Corrosion Cracking (SCC)
ELV	All	Notes 1,2	Note 3	Note 4

NOTES

1 Flammability requirements as defined in NHB 8060.1.

2 Flammability requirements specified in EWR 127-1, Paragraph 3.10.1.

3 Vacuum Outgassing requirements as defined in paragraph 6.2.5 2.

4. Stress corrosion cracking requirements as defined in MSFC-SPEC-522.

6.2.3 Conventional Applications

Conventional applications or usage of materials is the use of compliant materials in a manner for which there is extensive satisfactory aerospace heritage.

6.2.4 Nonconventional Applications

The proposed use of a compliant material for an application for which there is limited satisfactory aerospace usage shall be considered a nonconventional application. In that case, the material usage shall be verified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those methods. This information shall be provided to the GSFC Material Assurance Engineer during the design reviews or other project meetings.

6.2.5 Polymeric Materials

JPL shall document all polymeric materials and composites used in the as-designed materials and processes list. Material acceptability shall be determined on the basis of flammability, vacuum outgassing and all other materials properties relative to the application requirements and usage environment.

6.2.5.1 Flammability

Expendable launch vehicle (ELV) payload materials shall meet the requirements of EWR 127-1, Paragraph 3.10.1.

6.2.5.2 Vacuum Outgassing

Material vacuum outgassing shall be determined in accordance with ASTM E-595. A material is qualified on a product-by-product basis. GSFC may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon lot testing. Only materials that have a total mass loss (TML) <1.00% and a collected volatile condensable mass (CVCM) <0.10% will be approved for use in a vacuum environment unless a waiver is granted by the EOS Chemistry project.

6.2.5.3 Shelf-Life-Controlled Materials

Polymeric materials that have a limited shelf-life shall be controlled by a program that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints shall be included. The use of materials whose date code has expired requires that the developer demonstrate by means of appropriate tests that the properties of the materials have not been compromised for their intended use; such materials must be approved by the EOS Chemistry project by means of a waiver. All limited-life items, including piece parts in subassemblies, shall be included in the Limited-Life List as part of each instrument's Acceptance Data Package.

6.2.6 Inorganic Materials

JPL shall document all inorganic materials and composites as part of the as-designed material and processes list. When requested, JPL shall provide supporting applications data. The criteria specified in MSFC-SPEC-522 shall be used to determine that metallic materials meet the stress corrosion cracking criteria. The GSFC Materials Assurance Engineer shall have verbal discussions with JPL for each material usage that does not comply with the MSFC-SPEC-522 stress corrosion cracking requirements. Nondestructive evaluation requirements are contained in the ELV structure integrity requirements.

6.2.6.1 Fasteners

JPL shall comply with the procurement documentation and test requirements contained in GSFC S-313-100, entitled "Goddard Space Flight Center Fastener Integrity Requirements". These requirements apply to the fasteners used on both flight instruments only. Upon GSFC request, material test reports for fastener lots shall be available at JPL for review.

Fasteners made of plain carbon or low alloy steel shall be protected from corrosion. When plating is specified, it shall be compatible with the space environment. On steels harder than RC 33, plating shall be applied by a process that is not embrittling to the steel.

6.2.7 Lubrication

JPL shall document all lubrications as part of the as-designed materials and processes list. JPL may be requested to submit supporting applications data.

Lubricants shall be selected for use with materials on the basis of valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination effects.

All lubricated mechanisms shall be qualified by life testing in accordance with a life test plan or heritage of an identical mechanism used in identical applications.

6.3 PROCESS SELECTION REQUIREMENTS

JPL shall document all material processes used in the as-designed materials and processes list. Upon request, a copy of any process shall be submitted to GSFC for review. Manufacturing processes (e.g., lubrication, heat treatment, welding, chemical or metallic coatings), shall be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

6.4 PROCUREMENT REQUIREMENTS

6.4.1 Purchased Raw Materials

Raw materials purchased by JPL shall be accompanied by the results of nondestructive, chemical and physical tests, or a Certificate of Compliance.

6.4.2 Raw Materials Used in Purchased Products

JPL shall require that the suppliers meet the requirements of 6.4.1.

SECTION 7

RELIABILITY REQUIREMENTS

7.1 GENERAL REQUIREMENTS

JPL shall plan and implement a reliability program that interacts effectively with other program disciplines, including systems engineering, hardware design, and product assurance. The program shall be tailored in order to:

a. Demonstrate that redundant functions, including alternative paths and work-arounds, are independent to the extent practicable.

b. Demonstrate that stress applied to parts is not excessive.

c. Identify single failure items (points) for possible safety degradation.

d. Show that reliability design is in keeping with mission design life and that it is consistent among components, subsystems, and the instruments.

e. Identify limited-life items and ensure that special precautions are taken to conserve their useful life for on-orbit operations.

f. Select significant engineering parameters for the performance of trend analysis to identify performance trends during prelaunch activities.

g. Ensure that the design allows for ease of replacement of parts and components and that redundant paths are easily monitored.

7.2 RELIABILITY ANALYSES

Reliability analyses shall be performed concurrently with design so that identified problem areas can be addressed for timely consideration of corrective action.

7.2.1 Failure Modes and Effects Analysis and Critical Items List

A Failure Modes and Effects Analysis (FMEA) shall be performed early in the design phase to identify system design problems. As additional design information becomes available the FMEA shall be refined.

Failure modes shall be assessed at the subsystem interface level. Each failure mode shall be assessed for the effect at that level of analysis, the next higher level and upward. The failure mode shall be assigned a severity category based on the most severe effect caused by a failure.

Severity categories shall be determined in accordance with Table 7-1:

TABLE 7-1

SEVERITY CATEGORIES

Category	Severity Definition
1	Catastrophic Failure modes that could result in serious injury or loss of life (ground personnel), or loss of launch vehicle.
1R	Failure modes of identical or equivalent redundant hardware items that, if all failed, could result in category 1 effects.
1S	Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and leads to Severity Category 1 consequences.
2	Critical Failure modes that could result in loss of one or more mission objectives as defined by the EOS Chemistry project office.
2R	Failure modes of identical or equivalent redundant hardware items that could result in Category 2 effects if all failed.
3	Significant Failure modes that could cause degradation to mission objectives.
4	Minor Failure modes that could result in insignificant or no loss to mission objectives.

FMEA analysis procedures and documentation shall be performed in accordance with accepted practices. Failure modes resulting in Severity Categories 1, 1R, 1S or 2 shall be analyzed at greater depth, to the single parts if necessary, to identify the cause of failure.

Results of the FMEA shall be used to evaluate the design relative to requirements. Identified discrepancies shall be evaluated by JPL management and design groups for assessment of the need for corrective action. No single instrument failure shall prevent removal of power from that instrument.

The FMEA shall analyze redundancies to ensure that redundant paths are isolated or protected such that any single failure that causes the loss of a functional path shall not affect the other functional path(s) or the capability to switch operation to that redundant path.

All failure modes that are assigned to Severity Categories 1, 1R, 1S and 2, shall be discussed during each instrument's design reviews. In addition, rationale for each failure mode shall be included in the discussion.

The FMEA shall be made available to GSFC upon request.

7.2.2 Parts Stress Analyses

Each application of electrical, electronic, and electromechanical (EEE) parts, shall be subjected to stress analyses for conformance with the applicable derating guidelines. The analyses shall be performed at the most stressful values that result from specified performance and environmental requirements (e.g. temperature, voltage) on the assembly or component. The analyses shall be performed in close coordination with the peer reviews and thermal analyses, and they shall require input data from component-level design reviews. The analyses results shall be presented at both TES and MLS instrument PDRs and CDRs.

7.2.4 Reliability Assessments

JPL shall perform reliability assessments to:

(a) evaluate alternative design concepts, redundancy and cross-strapping approaches, and part substitutions; and identify the elements of the design which are the greatest detractors of system reliability

(b) identify those potential mission limiting elements and components that will require special attention in part selection, testing, environmental isolation, and/or special operations

(c) evaluate the impact of proposed engineering change and waiver requests on reliability.

The results of the reliability assessments shall be reported at both the TES and MLS instrument's PDR and CDR.

JPL shall integrate reliability assessments with the design process and other assurance practices. JPL shall describe how the reliability assessments will incorporate definitions of failure as well as alternate and degraded operating modes which clearly describe plausible acceptable and unacceptable levels of performance. Degraded operating modes shall include failure conditions that could be alleviated or reduced in significance through the implementation of work-arounds, via telemetry.

7.3 ANALYSIS OF TEST DATA

JPL shall fully utilize test information during the normal test program to assess flight equipment reliability performance and identify potential or existing problem areas.

7.3.1 Trend Analyses

JPL shall assess all subsystems and components to determine measurable parameters that relate to performance stability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing during the system integration and test phases. The monitoring shall be accomplished within the normal test framework; i.e., during functional tests, environmental tests, etc. JPL shall establish a system for recording and analyzing the parameters as well as any changes from the nominal even if the levels are within specified limits. Trend analysis data shall be reviewed with the operational personnel prior to launch. A list of subsystem and components to be assessed and the parameters to be monitored will be presented at the major design reviews.

7.3.2 Analysis of Test Results

JPL shall analyze test information, trend data, and failure investigations to evaluate reliability implications. Identified problem areas shall be documented and directed to the attention of JPL management for action.

7.4 LIMITED-LIFE ITEMS

Limited-Life items shall be identified and presented at the instrument design reviews, and will be provided in final format as part of the Acceptance Data Package. The presentation during the design reviews shall include the impact on mission parameters, responsibilities, and a list of limited-life items, including data elements as follows: expected life, required life, duty cycle, and rationale for selection. The useful life period starts with fabrication and ends with the completion of the final orbital mission.

The list of limited-life items should include selected structures, thermal control surfaces, solar arrays and electromechanical mechanisms. Atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, wear and fatigue should be used to identify limited-life thermal control surfaces and structure items. Mechanisms such as compressors, seals, bearings, valves, gyros, actuators, and scan devices should be included when aging, wear, fatigue and lubricant degradation limit their life. Records shall be maintained that allow evaluation of the cumulative stress (time and/or cycles) for limited-life items, starting when useful life is initiated and indicating the program activity that stressed the items. The use of an item whose expected life is less than its mission design life must be approved by the EOS Chemistry project by means of a waiver.

SECTION 8

QUALITY ASSURANCE REQUIREMENTS

8.1 QUALITY MANAGEMENT SYSTEM

JPL shall have a Quality Management System which shall meet the intent of ANSI/ASQC Q9001-1994.

8.2 QA MANAGEMENT SYSTEM REQUIREMENTS AUGMENTATION

The following requirements augment identified portions of ANSI/ASQC Q9001-1994.

8.2.2 Paragraph 4.13.2 of ANSI/ASQC Q9001-1994 is augmented as follows:

A problem/failure report (PFR) shall be written for any departure from a design, performance, testing, or handling requirement that affects the form, fit, or function of the flight instrument, ground support equipment that interfaces with the flight instrument, or that could compromise mission objectives.

Reporting of failures shall begin with the first power application at the instrument level. This reporting shall continue through formal acceptance of each instrument by GSFC. For software problems, failure reporting shall begin with the first test use of the software item with the hardware. Failure reporting shall be in accordance with the Document Requirements List Item No. 209.

SECTION 9

CONTAMINATION CONTROL

9.1 GENERAL

JPL shall plan and implement a contamination control program applicable to each instrument. The program establishes the specific cleanliness requirements and delineates the approaches in a Contamination Control Plan (CCP).

9.2 CONTAMINATION CONTROL PLAN

JPL shall prepare and submit a CCP that describes the procedures that will be followed to control contamination. The CCP shall define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware will meet its mission objectives. The CCP shall establish the implementation and describe the methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of both instruments. The CCP shall be submitted in accordance with the Documents Requirements List Item No. 023.

9.3 MATERIAL OUTGASSING

All materials shall be screened in accordance with NASA Reference Publication 1124. A list of material outgassing data shall be established and presented during the instrument design reviews for GSFC review.

9.4 THERMAL VACUUM BAKEOUT

Bake-outs of wiring harnesses and thermal blankets are required since past experience has shown these to be major contributors to the contamination level of hardware in test and flight. Bake-outs of critical subsystems before final instrument assembly shall also be necessary. During these bake-outs, the outgassing must be measured to ensure compliance with the allowances in Section 9.2. The parameters (e.g. verification method, temperature, duration, pressure) of such bake-outs must be individualized, depending on the materials used, the fabrication environment, and the established contamination allowance. The bake-out parameters for each hardware item shall be documented in individual bake-out specifications and referenced in the CCP.

JPL shall incorporate a quartz crystal mircobalance (QCM) and cold finger during all thermal vacuum bakeouts.

These devices shall provide additional information to enable a determination of the duration and effectiveness of the thermal vacuum bakeout as well as compliance with the instrument's contamination control plan.

9.5 HARDWARE HANDLING

JPL shall practice cleanroom standards in handling hardware. The contamination potential of material and equipment used in cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., antistatic film materials), and purging shall be addressed.

SECTION 10

SOFTWARE ASSURANCE

10.1 General

JPL shall develop a software management plan which covers ground, flight, and science software. This plan shall be in accordance with GSFC 424-28-11-01 entitled "Instrument Software Management Requirements Document for EOS Chemistry". Software assurance management shall be discussed in this plan.

JPL will hold internal software reviews at appropriate times in the program and will notify GSFC as to where and when these reviews will be held. JPL will formally present the software requirements at the time of the hardware PDR, and will report the software design information with the hardware CDR. The software test readiness and acceptance will formally be reported at the PER and PSR respectively.

The corrective action process shall start at the establishment of a Configuration Management baseline that includes the product. In no case shall the use of the formal software corrective action process be delayed beyond the use of the software in hardware for which formal problem reporting is required.

The GSFC shall be allowed access to the problem reports and the corrective action information as they are developed.

JPL shall establish an Software Configuration Management (SCM) baseline after each formal software review. Software products shall be placed under Configuration Management immediately after the successful conclusion of the review.

JPL's SCM system shall have a change classification and impact assessment process that results in Class 1 changes being forwarded to the EOS Chemistry project for disposition. Class 1 changes are defined as major changes which affect system requirements, software requirements, system safety, reliability, cost, schedule, and external interfaces.

10.2 GFE, Existing and Purchased Software

If JPL shall be provided software as government-furnished equipment (GFE), or shall use existing or purchased software, then JPL is responsible for the software meeting the functional, performance, and interface requirements placed upon it. JPL is responsible for ensuring that the software meets all applicable standards, including those for design, code, and documentation, or for securing a GSFC project waiver to those standards. Any significant modification to any piece of the existing software shall be subject to all of the provisions of JPL's Software Quality Management Systems and the provisions of this document. A significant modification is defined as the change of twenty percent of the lines of code in the software.

10.3 Software Safety

If any software component is identified as safety critical, JPL shall conduct a software safety program on that component that complies with Section 3.16 of EWR 127-1 (Tailored).

SECTION 11

SAFETY REQUIREMENTS

11.1 GENERAL REQUIREMENTS

JPL shall plan and conduct a system safety program for each instrument and all ground support equipment which interfaces with each instrument. The plan shall accomplish the following:

a. Provide for the identification and control of hazards to personnel, facilities, support equipment, and flight systems during all stages of project development and integration. The program shall also consider hazards in the flight hardware, software, and associated equipment and potential malfunctions in the instrument GSE that may affect the instrument.

b. Satisfy the applicable guidelines, constraints, and requirements stated in the revisions of the following document current at the time of signing the Working Agreement:

> Eastern & Western Range Safety Policies & Processes, EWR 127-1 (Tailored).

c. Interface effectively with the industrial safety requirements in this Section and JPL's existing safety programs.

11.2 SYSTEM SAFETY IMPLEMENTATION PLAN (SSIP)

JPL shall prepare a System Safety Implementation Plan (SSIP) which describes the safety program requirements, the plan for implementing them, and shall reference detailed procedures to ensure the identification and control of hazards to personnel and hardware during fabrication, tests, transportation, ground activities, launch, and mission operations.

The plan shall address the following areas: system safety organization, interfaces, and responsibilities; system safety methodologies; internal and external safety review process; launch site safety; verification and operating procedures; hazardous operation surveillance; accident investigation and reporting; operator training and certification; safety audits; monitoring of subcontractors; documentation to be provided; milestone schedule of all major system safety activities which shows their time phasing with other related major activities; procedure for reporting problems and activity status; and the industrial safety program responsibilities, functions, and interfaces with the system safety program.

The SSIP shall be available for review upon request. Also, all referenced documents in the SSIP shall be included with the plan.

11.3 STRUCTURAL INTEGRITY AND FRACTURE CONTROL

Verification of the structural integrity of the instrument is required. When protoflight testing to verify the structural design is conducted, no further verification of fracture control is required. Where such testing is not required, JPL shall verify structural integrity by subjecting the instrument hardware to an appropriate series of proof loads tests to limit levels.

11.4 ANALYSIS

11.4.1 Hazard Analysis

Early in the design phase, JPL shall perform hazard analyses to identify any potential hazard(s) originating from the instrument or JPL provided GSE. The analyses shall be performed at the component and instrument levels, and shall identify all hazards affecting personnel, instrument GSE, other system instruments, or either the TES/MLS instrument. The analyses shall be oriented to the requirements/hazards areas identified in Chapters 3 and 6 of EWR 127-1(Tailored) and shall provide all information necessary to complete the hazard identification and elimination/control requirements of the "Safety Assessment Report" (SAR). A separate Payload Hazard Report shall be generated for each hazard identified. The hazard report shall document the causes, controls, verification methods, and status of verification for each hazard.

Throughout the instrument development effort, the developer shall take measures to eliminate or to minimize the effects of each hazard identified. The hazard analysis and reports shall be updated as the hardware progresses through the stages of design, fabrication, test transportation, integration, and launch. The hazard analysis reports shall be included with the Safety Assessment Reports submittals (Document Requirements List Item No. 224).

Summaries of the Hazard Analysis Reports and the status of hazard control efforts shall be reported at the design and readiness reviews (see section 11.7).

11.4.2 Operation Hazard Analysis

When the use of a facility or the performance of an activity could result in subjecting the instrument or personnel to hazards, an Operations Hazard Analysis (OHA) shall be performed to identify the hazards and document the requirements for either eliminating or adequately controlling each hazard. Operations that may require analysis include handling, transportation, functional tests, and environmental test. A report of each OHA performed shall be submitted in accordance with the Document Requirements List Item No. 107.

11.5 HAZARD CONTROL VERIFICATION

Verification of the control of all hazards shall be accomplished by test, analysis, inspection, similarity to previously qualified hardware, or any combination of these activities. Reports of such verifications performed by JPL shall be incorporated in the Hazard Analysis Reports (see section 11.4.1).

11.6 PROCEDURE APPROVAL

JPL's safety engineer shall review and approve all procedures affecting flight hardware and provided GSE. Hazardous operations shall be identified and procedures to control them shall be developed and implemented.

11.7 REVIEWS

The instrument safety status shall be examined at the GSFC Flight Assurance Reviews as well as the other applicable Air Force Space Command Western Range (WR) safety reviews. The developer shall submit the current safety data at the time of the GSFC PDR, CDR, PER and all flight readiness reviews, as well as the WR phased safety reviews. The WR reviews are required as described in Appendix 1B of EWR 127-1 at the following instrument milestones:

Phase 1 - Around the time of GSFC PDR

Phase 2 - Around the time of GSFC CDR

Phase 3 - 90 days prior to shipping the instrument to the spacecraft contractor.

JPL shall provide data inputs required by the WR and technical support to the GSFC for all safety reviews. JPL shall review the systems safety program of subcontractors.

11.8 SAFETY DEVIATION/WAIVER

When a specific safety requirement can not be met, the developer shall submit a deviation/waiver request (DOD Form 1964). The deviation/waiver request shall state the requirement that cannot be met, the reason it cannot be met, the proposed method of controlling the additional risk, and the residual risk after application of the additional controls. Each deviation/waiver request shall address only one hazard and shall be submitted as soon as it is determined that one is required. EWR 127-1 requires that each phased safety review address any deviation/waiver requests that may have been generated. Safety deviation/waiver requests shall be submitted in accordance with the Document Requirements List Item No. 510.

11.9 SAFETY ASSESSMENT REPORT (SAR)

JPL shall submit to GSFC a Safety Assessment Report relative to the instrument which complies with the requirements of section 3.4.1.2 of EWR 127-1 (see par. 11.4.1, herein). The content of the package shall be appropriate to the phase of the program at the time of delivery and shall include the Instrument Hazard Reports (see sections 11.4.1 and 11.5). JPL shall include with the SAR, copies of any pertinent deviation/waiver requests that have been generated (see section 11.7 above) and shall update the SAR as necessary. The SAR shall be submitted to NASA in accordance with Document Requirements List Item No. 224.

11.10 FLAMMABILITY

Flammability hazards shall be minimized in the selection and application of materials in the design. Where any flammable materials must be used, the following hazard elimination and control requirements apply: (a) two failure tolerance on ignition sources, (b) physical separation of the flammable material from ignition sources, and (c) elimination of flame propagation paths.

SECTION 12

APPLICABLE DOCUMENTS

ANSI/ASQC Q9001-1994	Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/IPC-A-600	Acceptance Criteria for Printed Wiring Boards
ANSI/IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
ANSI/IPC-RB-276	Qualification and Performance Specification for Rigid Printed Boards
ASTM E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum Environment
EWR 127-1 (Tailored)	Eastern and Western Range Safety Requirements (As tailored for the EOS Common Spacecraft Projects)
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components, rev A, dated June 1996
GSFC 424 -28-11-01	Instrument Software Management Requirements Document for EOS Chemistry
GSFC PPL	Goddard Space Flight Center Preferred Parts List
JPL D-1348	Electrostatic Control for Assemblies and Test Areas

JPL D-8208	Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling
GSFC S-312-P003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
MIL-STD 1629A	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MIL-STD-756B	Reliability Modeling and Prediction
MIL-STD-975	NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List
MSFC CR 5320 9	Payload and Experiment Failure Mode Effects Analysis and Critical Items List Groundrules
MSFC-HDBK-527	Material Selection List for Space Hardware Systems
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA Reference Publication (RP) 1124	Outgassing Data for Selecting Spacecraft Materials
NASA RP-1161	Evaluation of Multilayer Printed Wiring Boards by Metallographic Techniques
NHB 8060.1	Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments That Support Combustion

NSS 1740.13	Software Safety Standard
NSTS 22648	Flammability Configuration Analysis for Spacecraft Applications
S-302-89-01	Procedures for Performing a Failure Mode and Effects Analysis (FMEA)

SECTION 13

ACRONYM LIST
&
DEFINITIONS

ACRONYMS

ANSI	American National Standards Institute
ASQC	American Society for Quality Control
ASIC	Application Specific Integrated Circuits
BOL	Beginning of Life
C	Celsius
CCP	Contamination Control Plan
CDR	Critical Design Review
CIL	Critical Items List
CPT	Comprehensive Performance Test
CVCM	Collected Volatile Condensable Mass
DPA	Destructive Physical Analysis
DRP	Design Review Program
EEE	Electrical, Electronic, and Electromechanical
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
FMEA	Failure Modes and Effects Analysis
GEVS	General Environmental Verification Specification
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components
GFE	Government-Furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LPT	Limited Performance Test
MCM	Multi-Chip Module
MO&DSD	Mission Operations and Data Systems Directorate
MOR	Mission Operations Review
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications Network
NSTS	National Space Transportation System
OFA	Office of Flight Assurance
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PFR	Problem/Failure Report
PI	Principal Investigator
PIL	Parts Identification List
POCC	Payload Operations Control Center
PPL	Preferred Parts List
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QCM	Quartz Crystal Microbalance
RFP	Request for Proposal
RH	Relative Humidity
SCC	Stress Corrosion Cracking
SCD	Source Control Drawing
SCM	Software Configuration Management

SOCC	Simulations Operations Control Center
SOW	Statement of Work
SQMS	Software Quality Management System
SRO	Systems Review Office
SRR	Software Requirements Review
TML	Total Mass Loss
TR	Torque Ratio
TRR	Test Readiness review

DEFINITIONS

The following definitions apply within the context of this document:

Acceptance Tests: The verification process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and, normally, to provide the basis for delivery of an item under terms of a contract.

Assembly: See Level of Assembly.

Audit: A review of the developer's, contractor's or subcontractor's documentation or hardware to verify that it complies with project requirements.

Collected Volatile Condensable Material (CVCM): The quantity of outgassed matter from a test specimen that condenses on a collector maintained at a specific constant temperature for a specified time.

Component: See Level of Assembly.

Configuration: The functional and physical characteristics of the payload and all its integral parts, assemblies and systems that are capable of fulfilling the fit, form and functional requirements defined by performance specifications and engineering drawings.

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes and implementation of all approved changes to the design and production of an item the configuration of which has been formally approved by the contractor or by the purchaser, or both.

Configuration Management: The systematic control and evaluation of all changes to baseline documentation and subsequent changes to that documentation which define the original scope of effort to be accomplished (contract and reference documentation) and the systematic control, identification, status accounting and verification of all configuration items.

Contamination: The presence of materials of molecular or particulate nature which degrade the performance of hardware.

Derating: The reduction of the applied load (or rating) of a device to improve reliability or to permit operation at high ambient temperatures.

Design Specification: Generic designation for a specification that describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements. The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects the end-item specifications serve all the purposes of design specifications for the contract end-items. Design specifications provide the basis for technical and engineering management control.

Destructive Physical Analysis (DPA): An internal destructive examination of a finished part or device to assess design, workmanship, assembly, and any other processing associated with fabrication of the part.

Discrepancy: See Nonconformance.

Design Qualification Tests: Tests intended to demonstrate that the test item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations. Their purpose is to uncover deficiencies in design and method of manufacture. They are not intended to exceed design safety margins or to introduce unrealistic modes of failure. The design qualification tests may be to either "prototype" or "protoflight" test levels.

Discrepancy: See Nonconformance

Electromagnetic Compatibility (EMC): The condition that prevails when various electronic devices are performing their functions according to design in a common electromagnetic environment.

Electromagnetic Susceptibility: Undesired response by a component, subsystem, or system to conducted or radiated electromagnetic emissions.

End-to-End Tests: Tests performed on the integrated ground and flight system, including all elements of the payload, its control, stimulation, communications, and data processing to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Failure: A departure from specification that is discovered in the functioning or operation of the hardware or software. See nonconformance.

Failure Modes and Effects Analysis (FMEA): A procedure by which each credible failure mode of each item from a low indenture level to the highest is analyzed to determine the effects on the system and to classify each potential failure mode in accordance with the severity of its effect.

Flight Acceptance: See Acceptance Tests.

Fracture Control Program: A systematic project activity to ensure that a payload intended for flight has sufficient structural integrity as to present no critical or catastrophic hazard. Also to ensure quality of performance in the structural area for any payload (spacecraft) project. Central to the program is fracture control analysis, which includes the concepts of fail-safe and safe-life, defined as follows:

a. **Fail-safe**: Ensures that a structural element, because of structural redundancy, will not cause collapse of the remaining structure or have any detrimental effects on mission performance.

b. **Safe-life**: Ensures that the largest flaw that could remain undetected after non-destructive examination would not grow to failure during the mission.

Functional Tests: The operation of a unit in accordance with a defined operational procedure to determine whether performance is within the specified requirements.

Hardware: As used in this document, there are two major categories of hardware as follows:

a. **Prototype Hardware:** Hardware of a new design; it is subject to a design qualification test program; it is not intended for flight.

b. **Flight Hardware:** Hardware to be used operationally in space. It includes the following subsets:

   (1) **Protoflight Hardware:** Flight hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and flight acceptance test durations.

   (2) **Follow-On Hardware:** Flight hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to a flight acceptance test program.

   (3) **Spare Hardware:** Hardware the design of which has been proven in a design qualification test program; it is subject to a flight acceptance test program and is used to replace flight hardware that is no longer acceptable for flight.

   (4) **Reflight Hardware:** Flight hardware that has been used operationally in space and is to be reused in the same way; the verification program to which it is subject depends on its past performance, current status, and the upcoming mission.

Inspection: The process of measuring, examining, gauging, or otherwise comparing an article or service with specified requirements.

Instrument: See Level of Assembly.

Level of Assembly: The environmental test requirements of GEVS generally start at the component or unit level assembly and continue hardware/software build through the system level (referred to in GEVS as the payload or spacecraft level). The assurance program includes the part level. Verification testing may also include testing at the assembly and subassembly levels of assembly; for test record keeping these levels are combined into a "subassembly" level. The verification program continues through launch, and on-orbit performance. The following levels of assembly are used for describing test and analysis configurations:

Assembly: A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and gyroscope.

Component: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.

Instrument: A spacecraft subsystem consisting of sensors and associated hardware for making measurements or observations in space. For the purposes of this document, an instrument is considered a subsystem (of the spacecraft).

Module: A major subdivision of the payload that is viewed as a physical and functional entity for the purposes of analysis, manufacturing, testing, and record keeping. Examples include spacecraft bus, science payload, and upper stage vehicle.

Part: A hardware element that is not normally subject to further subdivision or disassembly without destruction of design use. Examples include resistor, integrated circuit, relay, connector, bolt, and gaskets.

Payload: An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Section: A structurally integrated set of components and integrating hardware that form a subdivision of a subsystem, module, etc. A section forms a testable level of assembly, such as components/units mounted into a structural mounting tray or panel-like assembly, or components that are stacked.

Spacecraft: See Payload. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Subassembly: A subdivision of an assembly. Examples are wire harness and loaded printed circuit boards.

Subsystem: A functional subdivision of a payload consisting of two or more components. Examples are structural, attitude control, electrical power, and communication subsystems. Also included as subsystems of the payload are the science instruments or experiments.

Unit: A functional subdivision of a subsystem, or instrument, and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.

Limit Level: The maximum expected flight.

Limited Life Items: Spaceflight hardware (1) that has an expected failure-free life that is less than the projected mission life, when considering cumulative ground operation, storage and on-orbit operation, (2) limited shelf life material used to fabricate flight hardware.

Margin: The amount by which hardware capability exceeds mission requirements

Module: See Level of Assembly.

Monitor: To keep track of the progress of a performance assurance activity; the monitor need not be present at the scene during the entire course of the activity, but he will review resulting data or other associated documentation (see Witness).

Nonconformance: A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. As applied in quality assurance, nonconformances fall into two categories--discrepancies and failures. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Offgassing: The emanation of volatile matter of any kind from materials into a manned pressurized volume.

Outgassing: The emanation of volatile materials under vacuum conditions resulting in a mass loss and/or material condensation on nearby surfaces.

Part: See Level of Assembly.

Payload: See Level of Assembly.

Performance Verification: Determination by test, analysis, or a combination of the two that the payload element can operate as intended in a particular mission; this includes being satisfied that the design of the payload or element has been qualified and that the particular item has been accepted as true to the design and ready for flight operations.

Protoflight Testing: See Hardware.

Prototype Testing: See Hardware.

Qualification: See Design Qualification Tests.

Redundancy (of design): The use of more than one independent means of accomplishing a given function.

Repair: A corrective maintenance action performed as a result of a failure so as to restore an item to op within specified limits.

Rework: Return for completion of operations (complete to drawing). The article is to be reprocessed to conform to the original specifications or drawings.

Section: See Level of Assembly.

Similarity, Verification by,: A procedure of comparing an item to a similar one that has been verified. Configuration, test data, application, and environment should be evaluated. It should be determined that design-differences are insignificant, environmental stress will not be greater in the new application, and that manufacturer and manufacturing methods are the same.

Single Point Failure: A single element of hardware the failure of which would result in loss of mission objectives, hardware, or crew, as defined for the specific application or project for which a single point failure analysis is performed.

Spacecraft: See Level of Assembly.

Subassembly: See Level of Assembly.

Subsystem: See Level of Assembly.

Temperature Cycle: A transition from some initial temperature condition to temperature stabilization at one extreme and then to temperature stabilization at the opposite extreme and returning to the initial temperature condition.

Temperature Stabilization: The condition that exists when the rate of change of temperatures has decreased to the point where the test item may be expected to remain within the specified test tolerance for the necessary duration or where further change is considered acceptable.

Thermal Balance Test: A test conducted to verify the adequacy of the thermal model, the adequacy of the thermal design, and the capability of the thermal control system to maintain thermal conditions within established mission limits.

Thermal-Vacuum Test: A test conducted to demonstrate the capability of the test item to operate satisfactorily in vacuum at temperatures based on those expected for the mission. The test, including the gradient shifts induced by cycling between temperature extremes, can also uncover latent defects in design, parts, and workmanship.

Total Mass Loss (TML): Total mass of material outgassed from a specimen that is maintained at a specified constant temperature and operating pressure for a specified time.

Unit: See Level of Assembly.

Verification: See Performance Verification.

Vibroacoustics: An environment induced by high-intensity acoustic noise associated with various segments of the flight profile; it manifests itself throughout the payload in the form of directly transmitted acoustic excitation and as structure-borne random vibration.

Workmanship Tests: Tests performed during the environmental verification program to verify adequate workmanship in the construction of a test item. It is often necessary to impose stresses beyond those predicted for the mission in order to uncover defects. Thus random vibration tests are conducted specifically to detect bad solder joints, loose or missing fasteners, improperly mounted parts, etc. Cycling between temperature extremes during thermal-vacuum testing and the presence of electromagnetic interference during EMC testing can also reveal the lack of proper construction and adequate workmanship.

Witness: A personal, on-the-scene observation of a performance assurance activity with the purpose of verifying compliance with project requirements (see Monitor).